The p-T coexistence line of nuclear matter: ISiS results

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In Fisher's droplet model [1] a non-ideal fluid is approximated by an ideal gas of droplets. Thus, summing over n_A, the normalized yield of droplets of size A, gives the total pressure and the reduced pressure is:

$$\frac{p}{p_c} = \frac{T \sum n_A(\Delta\mu, E_{Coul}, T)}{T_c \sum n_A(\Delta\mu, E_{Coul}, T_c)}. \qquad (1)$$

The coexistence line for finite neutral nuclear matter is obtained by substituting the $n_A(\Delta\mu = 0, E_{Coul} = 0, T)$ in the numerator of Eq. (1) and $n_A(\Delta\mu = 0, E_{Coul} = 0, T_c)$ in the denominator.

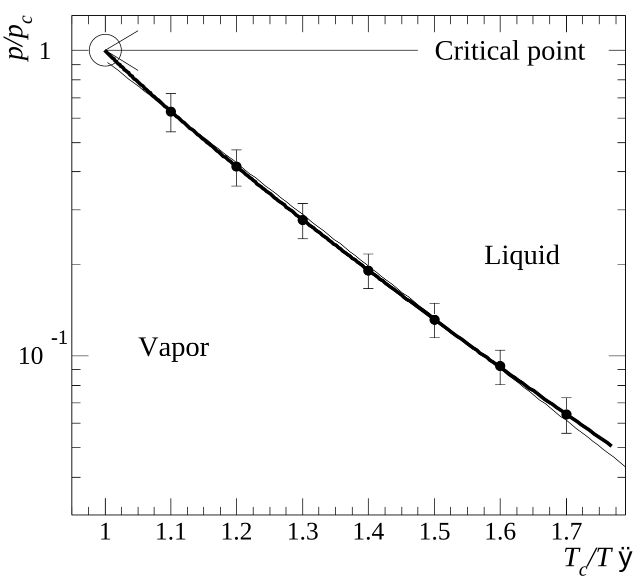

Figure 1: The reduced pressure-temperature phase diagram: the thick line shows the calculated coexistence line, the points show selected calculated errors and the thin line shows a fit to the Clausius-Clapeyron equation.

Figure 1 gives an estimate of the coexistence line of finite neutral nuclear matter, based on an analysis of the ISiS fragment yields of 8 GeV/c π + Au [1]. From this it is possible to make an estimate of the bulk binding energy of nuclear matter. Beginning with the Clausius-Clapeyron equation

$$\frac{\partial p}{\partial T} = \frac{\Delta H}{T \Delta V} \qquad (2)$$

and solving for the vapor pressure with

$$\Delta V = V_{vapor} - V_{liquid} \approx V_{vapor} = \frac{T}{p} \qquad (3)$$

one obtains

$$p = p_0 \exp(\frac{-\Delta H}{T}) \qquad (4)$$

which leads to the ratio of

$$\frac{p}{p_c} = \exp\left[\frac{\Delta H}{T_c}\left(1 - \frac{T_c}{T}\right)\right]. \qquad (5)$$

where ΔH is the molar enthalpy of evaporation. Equation (5) is empirically observed to describe several fluids up to T_c.

A fit of Eq. (5) to the coexistence line gives the ratio of $\Delta H/T_c$. Using the value of $T_c = 6.7 \pm 0.2$ MeV [1] gives the molar enthalpy of evaporation of the liquid $\Delta H = 26 \pm 1$MeV. From ΔH ΔE is found via $\Delta E = \Delta H - pV$ with $pV = T$ using the average temperature from the range in Fig. 1, $\langle T \rangle \approx 4$MeV. ΔE refers to the cost in energy to evaporate a single *fragment*. To determine the energy cost on a per nucleon basis ΔE is devided by the average size of a fragment over the temperature range in Fig. 1. Since the gas described by Fisher's model is an ideal gas of droplets, the average droplet size is greater in size than a monomer and in the region of the p-T coexistence line is ~ 1.5. Thus the $\Delta E/A$ becomes $\sim$15 AMeV, close to the nuclear bulk energy coefficient of 15.5 MeV.

References

[1] J. B. Elliott *et al.*, Phys. Rev. Lett. **88**, 042701 (2002).